

Chapter - 4

FEATURE RECOGNITION

CHAPTER - IV

FEATURE RECOGNITION

From the earlier discussion, once the neutral files (STEP files) of geometric models are imported, the geometrical extraction is carried out. As mentioned earlier, various rules can be applied / used for feature recognition process. These features are divided into four categories - namely cylindrical features, curved features, cross hole features and special features. In cylindrical feature recognition category, addition and subtraction (cylindrical hole) of cylinders is considered and online and offline recognition is also developed. Cylinder can be through or blind in nature.

4.1 CYLINDRICAL FEATURE RECOGNITION (CFR)

In this section, recognition of various cylindrical and conical features is described. This feature is basically recognized with a string `CYLINDRICAL_SURFACE` and `CONICAL_SURFACE` in STEP file.

4.1.1 Flowchart for Cylindrical Feature Recognition

Generally in rotational parts cylinder and cone are basic turning features. These features can be external or internal. For manufacturing the part dimensions are required. So, dimensions radius and length is found. These aspects are explained through a flowchart shown in Figure 4.1.

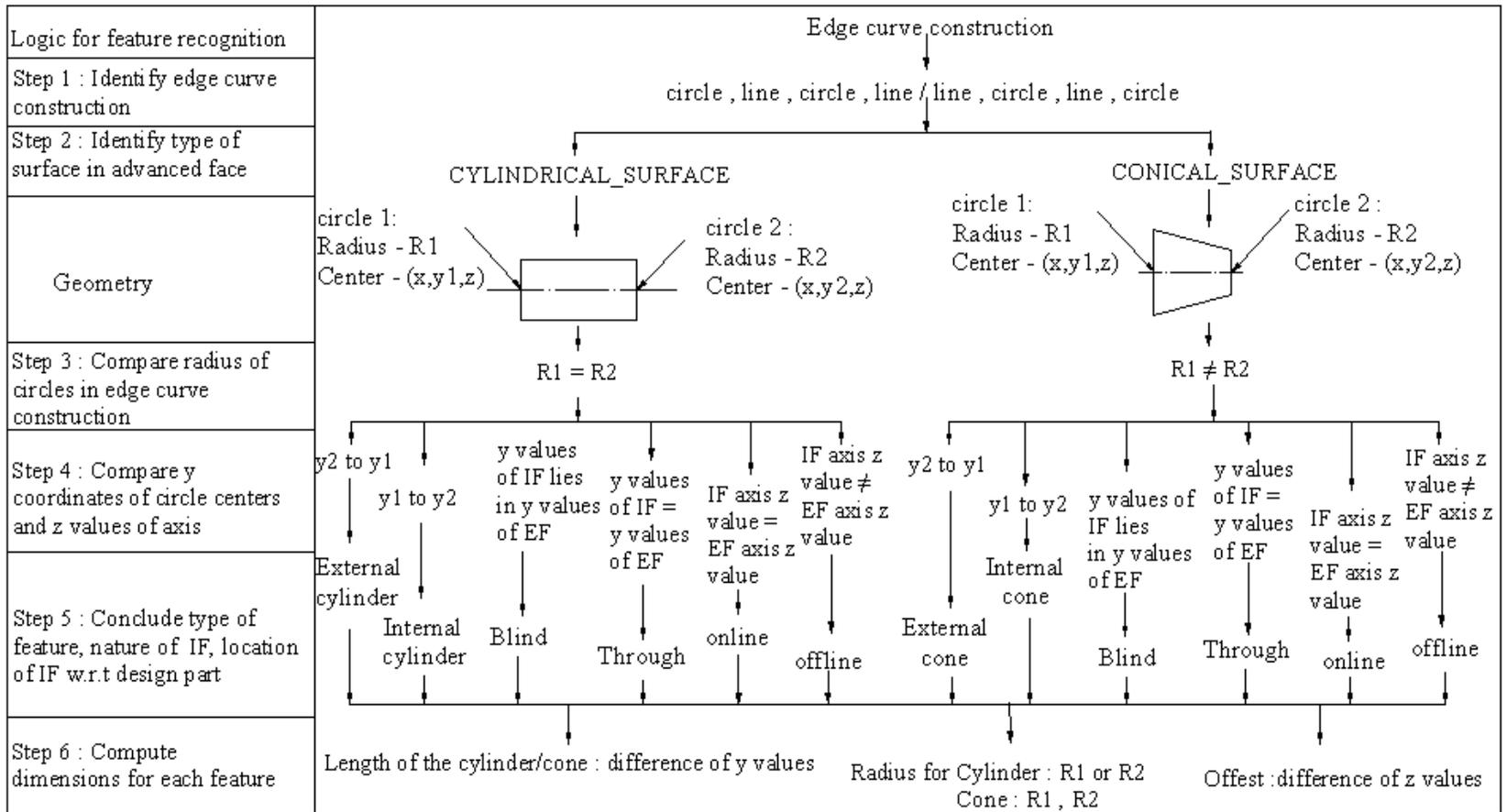


Fig. 4.1: Flowchart for cylindrical feature recognition

4.1.2 Recognition of a Cylinder

A cylinder is generated with two circles on two parallel planes and these two circles are bound by a surface. The geometry is shown in Figure 4.2 in which circle 1 center is (x, y_1, z) and circle 2 center is (x, y_2, z) . From circle coordinates it can be concluded that y coordinate is only varying and x and z coordinates same. From this it can be concluded that cylinder is symmetrical about y axis. For a longitudinal cylinder both circle radii are same.

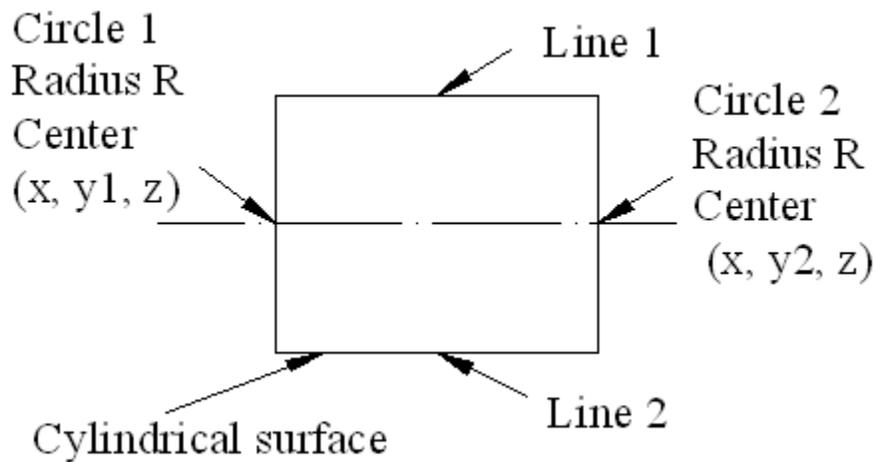


Fig. 4.2: Cylindrical feature geometry

4.1.3 Addition of a Cylinder

A cylinder can be added to another cylinder. This added cylinder axis can be online with other cylinder axis. This can be recognized from the axis placement coordinates.

As shown in Figure 4.3, addition of a cylinder is recognized if circle center y value varies from y_1 to y_2 for cylinder 1 and from y_2 to y_3 for cylinder 2 which means where y value of cylinder 1 is ending from there y value of cylinder 2 starts for added cylinder.

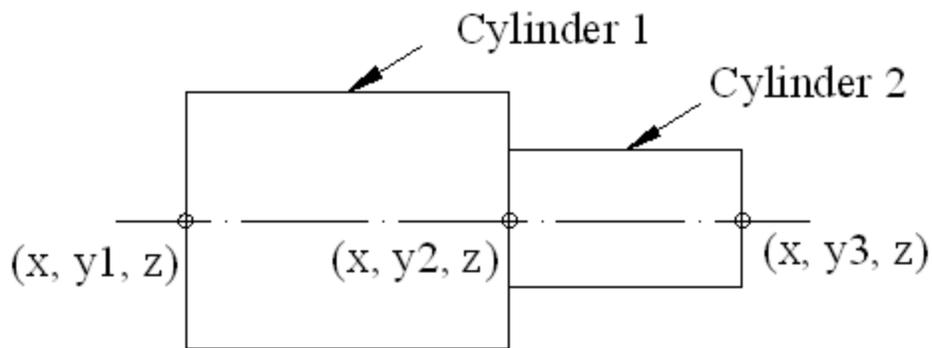


Fig. 4.3: Addition of a cylinder

4.1.4 Subtraction of a Cylinder (Cylindrical Hole)

When a cylinder is subtracted from another cylinder then a cylindrical hole is formed. Then outside cylinder is external cylinder and hole is internal cylinder. External features are recognized from right to left and internal features are recognized from left to right. As shown in Figure 4.4 external cylinder y value varies from point 2 to point 1 and for internal cylinder y value varies from point 1 to point 2 when cylinder is symmetrical about y axis.

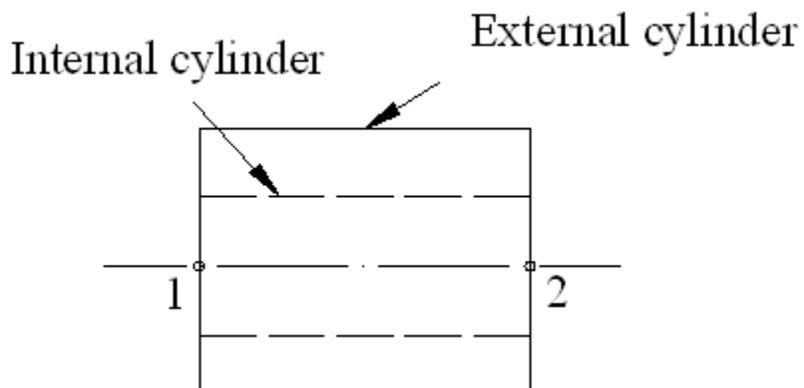


Fig. 4.4: Cylindrical hole feature geometry

4.1.5 Recognition of Online Cylindrical Features

Cylinder 2 is added to cylinder 1 as shown in Figure 4.5. In this axis of cylinder 2 is in same line with axis of cylinder1. From this it can be concluded that cylinder1 and cylinder 2 are online. This can be recognized from extracted data of STEP file. For this axis location for the cylinders is required. If z value of cylinder axis for both the cylinders (cylinder 1 and cylinder2) is same then cylinder 2 is online to cylinder1.

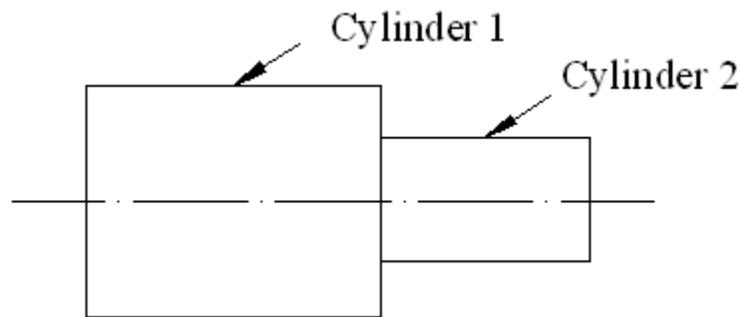


Fig. 4.5: Cylindrical online feature geometry

4.1.6 Recognition of Offline Cylindrical Features

As shown in Figure 4.6, cylinder 2 is added to cylinder 1 but axis of cylinder 2 is not online with cylinder1. This can be recognized, if z value of cylinder axis for both the cylinder (cylinder 1 and cylinder2) is different, then cylinder 2 is offline to cylinder1. If axis z value for cylinder 1 is less than axis z value of cylinder 2 then cylinder 2 is offset from cylinder1. If offset value is negative then axis of cylinder 2 is below the axis of cylinder1. Else axis of cylinder 2 is above the axis of cylinder1.

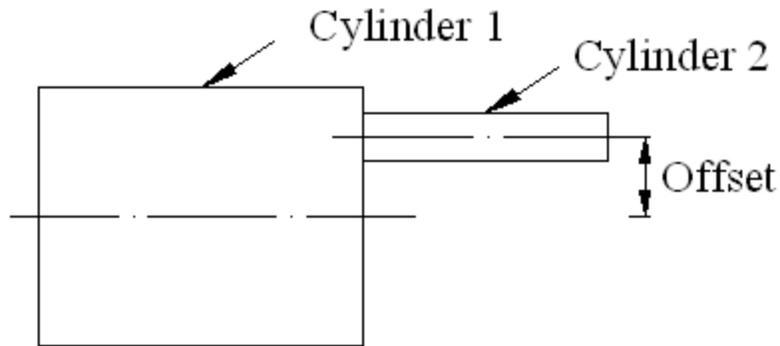


Fig. 4.6: Cylindrical offline feature geometry

4.1.7 Recognition of Cylindrical Hole - Through or Blind

The subtracted cylinder is called as hole. This hole can be through or blind in nature. This can be recognized by comparing the lengths of external cylinder and internal cylinder (hole) lengths. As shown in Figure 4.7, if the length of internal and external cylinders is same then it is a through hole. Alternatively, if the length of the internal cylinder is less than the external cylinder then it is a blind hole. If y values of internal cylinder lies between y values of external cylinder then it is considered as internal cylinder existing on that external cylinder.

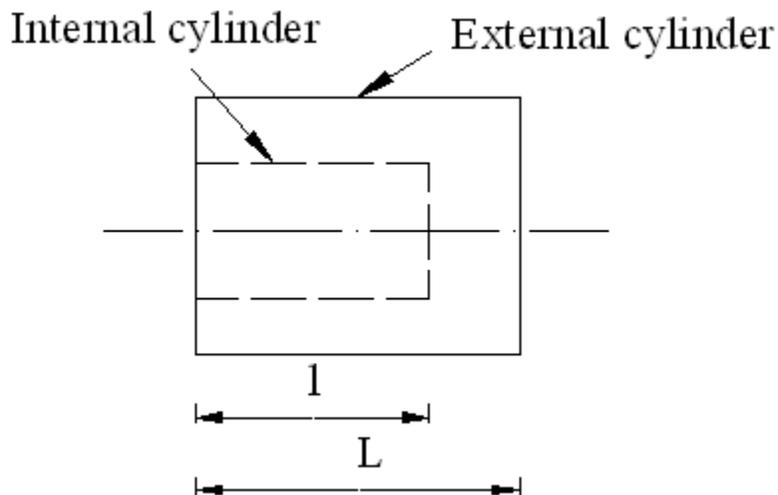


Fig. 4.7: Cylindrical hole through or blind geometry

4.1.8 Recognition of Cylindrical Hole Inclined to External Cylinder Axis

When axis of cylindrical hole is inclined to the axis of external cylinder then cylindrical hole on either ends is B-splines instead of circles. The geometry is shown in Figure 4.8.

An EDGE_CURVE for inclined cylindrical hole is constructed by two lines and two B-Splines.

A line is made up of two Cartesian points P1 and P2 of coordinates (x_1, y_1, z) and (x_2, y_2, z) respectively. The inclination is found using the following formula:

$$\tan \alpha = (x_2 - x_1) / (y_2 - y_1)$$

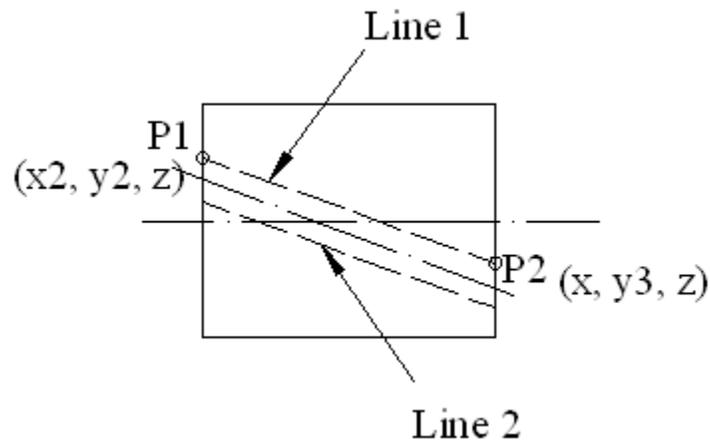


Fig. 4.8: Cylindrical hole inclined to external cylinder axis geometry

4.1.9 Recognition of Conical Features

A conical feature is generated with different circle radius on two parallel planes and bound by a surface. A conical feature can be external or internal. The geometry is shown in Figure 4.9.

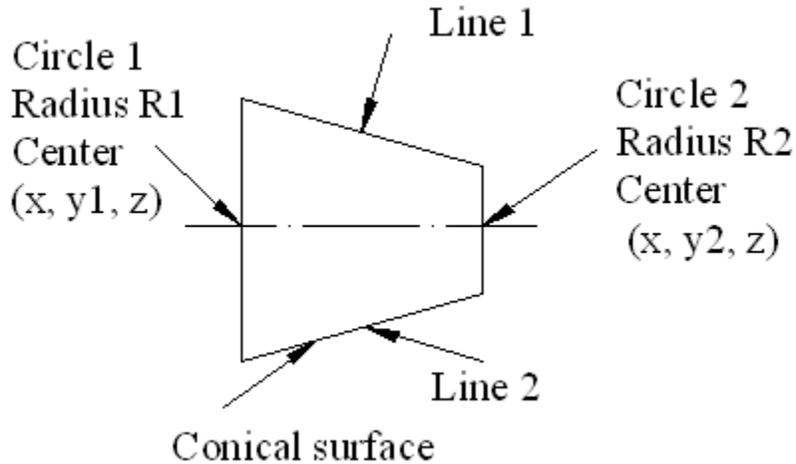


Fig. 4.9: Conical feature geometry

4.1.10 Recognition of Conical Hole Features

A conical cylinder can be subtracted from another cylinder. Recognition of conical feature is same as explained in section 4.1.9 but, to find external or internal feature y coordinates of the circles must be compared. If the circle center y coordinates of conical feature values varies from y_2 to y_1 then it is an internal conical hole. Conical hole can be through or blind. It is recognized that if length of the conical hole is less than external cylinder length then it is a blind conical hole and if both the lengths are equal then it is a through hole. The geometry is shown in Figure 4.10.

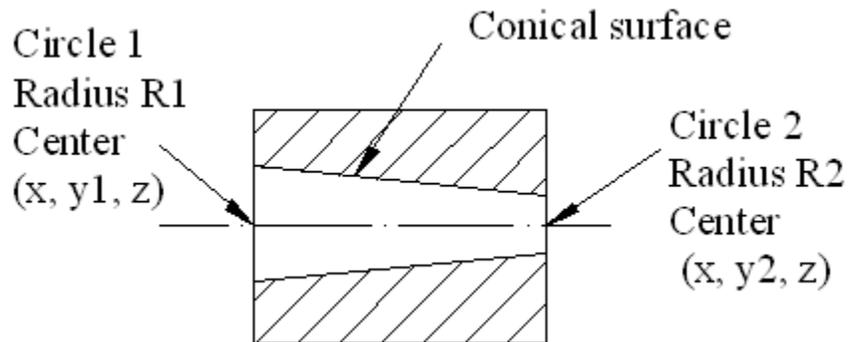


Fig. 4.10: Conical hole feature geometry

4.2 CURVATURE FEATURE RECOGNITION (CUFR)

In this chapter, recognition of various curvature features is described. This feature is basically recognized with a string Toroidal in STEP file. Curvatures can be concave or convex. Again concave and convex features can be external or internal. In addition to the above all features spherical feature is also described.

4.2.1 Flow Chart for Curvature Feature Recognition

A [fillet](#) is the rounding off of an interior corner. A rounding of an exterior corner is called a "round" or a "radius". In rotational components fillet is one of the manufacturing feature. This is provided to avoid sharp features. For drawing an arc / fillet center of arc and radius of arc is required. Existence of curvature feature is recognized with a TOROIDAL_SURFACE string in STEP file. This can be explained by two lines of a STEP file as shown below.

```
#123=ADVANCED_FACE('PartBody',(#122),#97,.T.) ;.....Line1  
#97=TOROIDAL_SURFACE('homeo Torus',#96,20.,10.) ;.....Line2
```

In first line entity#123 indicates ADVANCED_FACE string and last entity (#97) is connected to TOROIDAL_SURFACE string. Last number without # (10) indicates radius of the torus.

In STEP file EDGE_CURVE string line contains T or F letter at the end as shown below.

```
#49=EDGE_CURVE (" ,#46,#48,#44,.T.) ;
```

Depending on the edge curve T/F construction for each advanced face arc center inside or outside can be found. The curvature feature recognition module is explained through a flow chart in Figure 4.11.

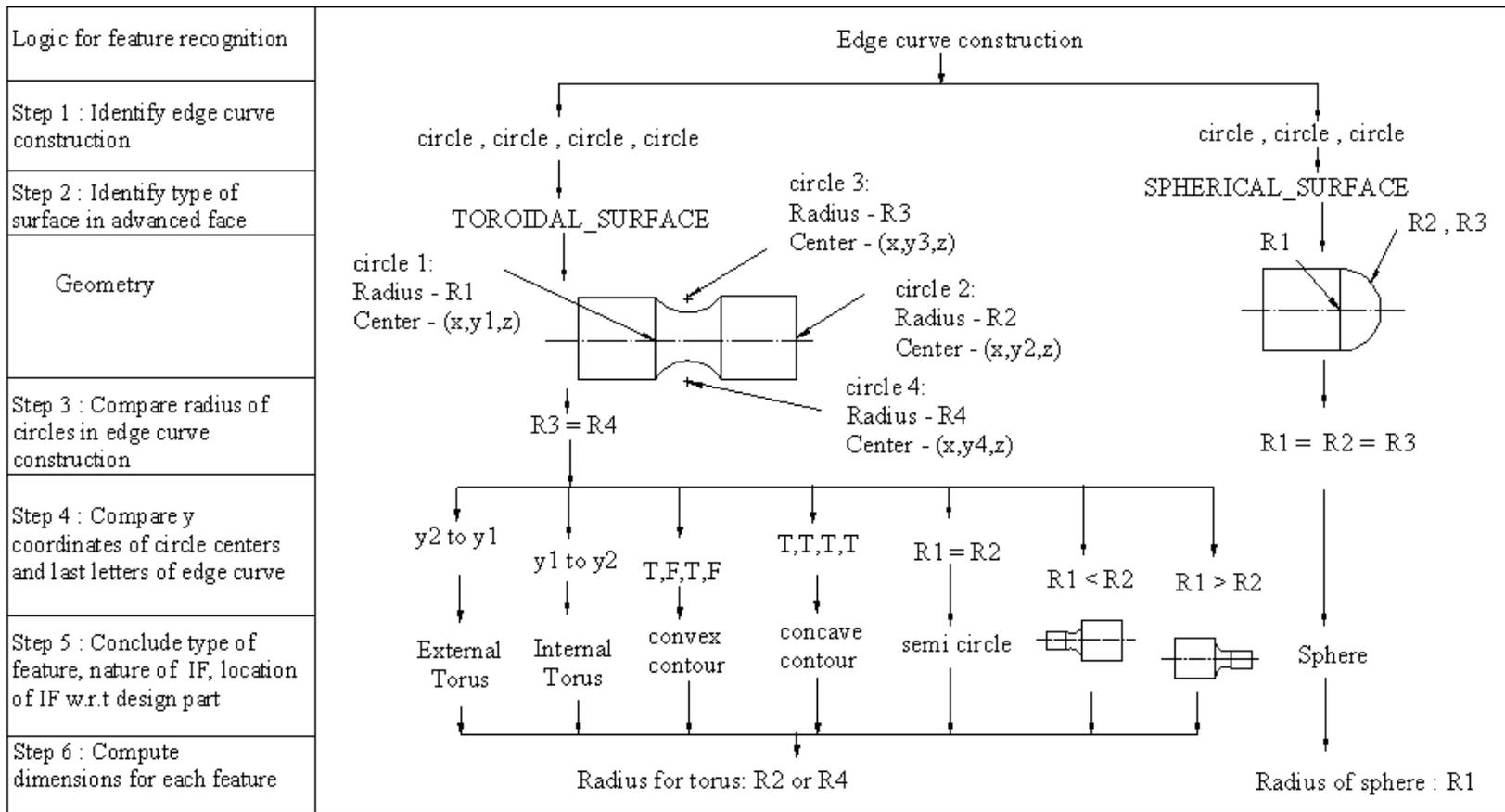


Fig. 4.11: Flow chart of curvature feature recognition

4.2.2 Recognition of Concave / Convex External Toroidal Features

Toroidal surface can exist between two features or after a feature. Like toroidal surface can exist between two cylinders or in between one cylinder and one cone or after a cylinder or after a cone. The contour of the curvature can be concave or convex in shape. EDGE_CURVE is constructed by four circles. The geometry of toroidal feature is shown in Figure 4.12. If EDGE_CURVE last letters construction is T, F, T, F then it is concave external toroidal feature. The radius of the torus is found from the TOROIDAL_SURFACE last entity number. If EDGE_CURVE is constructed with four circles and T, T, T, T then it is convex external toroidal feature.

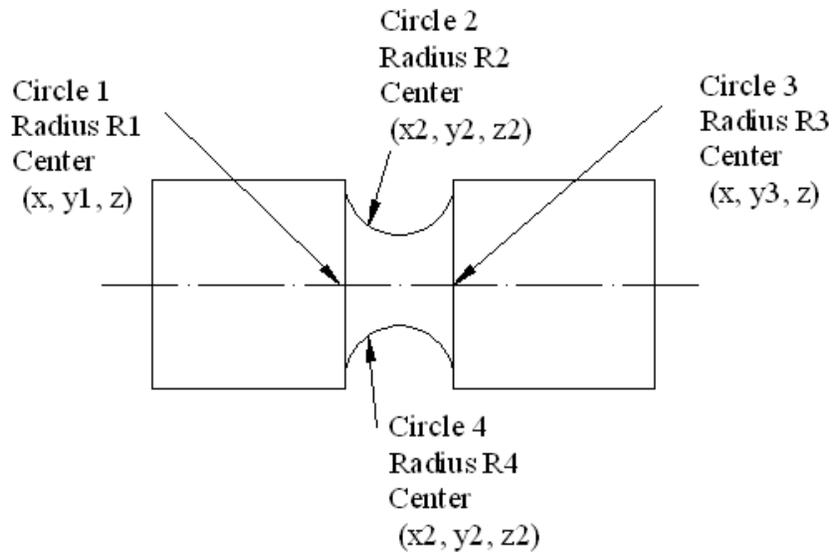


Fig. 4.12: Geometry of external toroidal features

4.2.3 Recognition of Concave / Convex Internal Toroidal Features

Figure 4.13 shows internal torus. Recognition of toroidal feature is same as explained in section 4.2.2. EDGE_CURVE constructed by four circles. In which first circle radius is $R1$ which is left side cylindrical hole radius and third circle radius is $R3$ which indicates the right side cylindrical hole radius. Centers of circle coordinates are $(x, y1, z)$ and $(x, y3, z)$. If y coordinate varies from $y3$ to $y1$ it is recognized as internal feature.

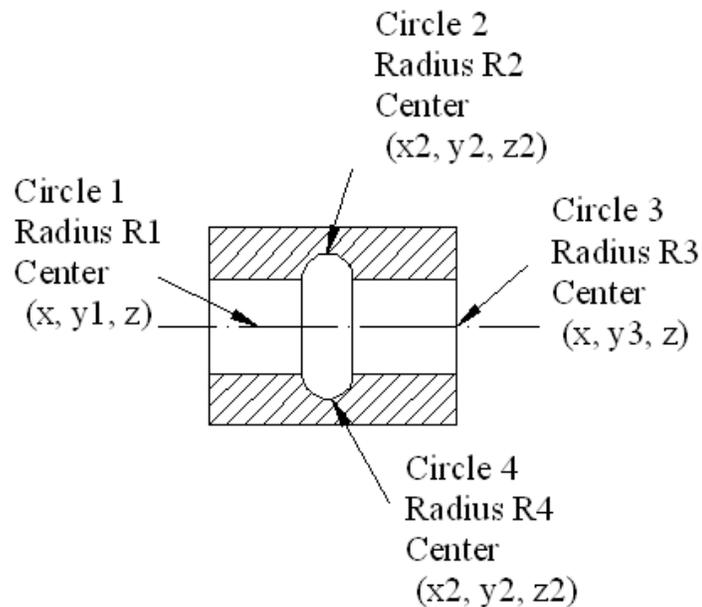


Fig. 4.13: Geometry of internal toroidal features

4.2.4 Recognition of Spherical Features

Geometry of spherical feature is shown in Figure 4.14. The radius of spherical surface is found from the last number of SPHERICAL_SURFACE of the STEP file. It is explained with two lines of a STEP file as shown below. In line 1 entity #67 is connected to string ADVANCED_FACE. In this line entity #40 is connected to SPHERICAL_SURFACE string. Last number without # indicates radius of the sphere (5).

```
#67=ADVANCED_FACE('PartBody',(#66),#40,.T.).....line1
#40=SPHERICAL_SURFACE("#39,5.) .....line2
```

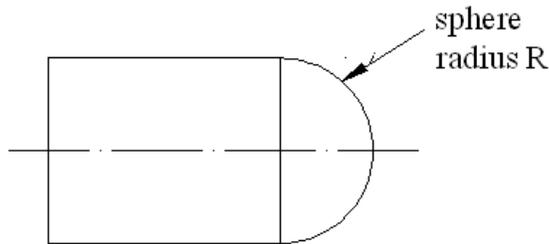


Fig. 4.14: Spherical feature geometry

4.3 CYLINDRICAL CROSS HOLE FEATURE RECOGNITION (CHFR)

In designing, a cross hole is formed when a cylinder is subtracted from cylindrical surface. These are produced by using 3-Axis machines. In this chapter, recognition of cylindrical cross hole features is described. This feature is basically recognized with existence of B-spline in STEP file. Cross holes can be perpendicular to the cylinder or inclined to axis of the cylinder. Cross hole can be through or blind. These are further described in following sections.

4.3.1 Flow Chart for Cylindrical Cross Hole Feature Recognition

Cross hole can be recognized from STEP file. This procedure is explained through two lines of a STEP file as shown below. In line 1 entity #284 indicates string of EDGE_CURVE. In this line last entity #261 is connected to B_SPLINE_CURVE_WITH_KNOTS. In EDGE_CURVE construction 'b-spline' string is placed.

```
#284=EDGE_CURVE("#281,#283,#261,.T.) ; .....line1
```

```
#261=B_SPLINE_CURVE_WITH_KNOTS(",5,(#262,#263,#264,#265,#266,#267,#268,#269,#270,#271,#272,#273,#274,#275,#276,#277,#278,#279),.UNSPECIFIED.,.F.,.U.,(6,3,3,3,3,6),(0.,7.17674482913,11.1830451672,14.1889930461,16.883820273,24.5333411894),.UNSPECIFIED.)  
;.....line2
```

If there is an existence of bspline in EDGE_CURVE construction then there is a cross hole on a cylinder. Flow chart for cross hole feature recognition is depicted in Figure 4.15.

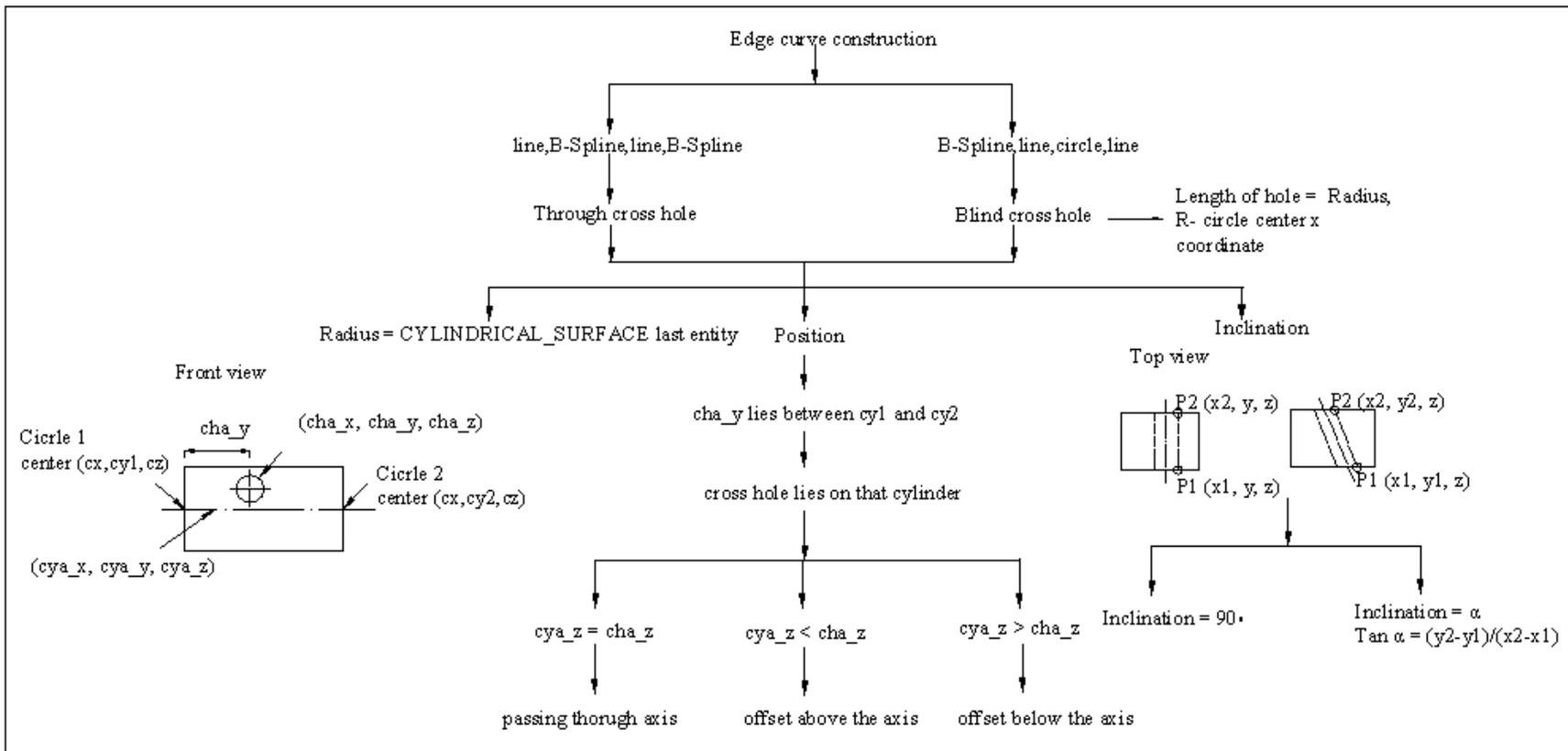


Fig. 4.15: Flow chart for cylindrical cross hole feature recognition

4.3.2 Recognition of a Cylindrical Cross Hole Passing Through Axis Line

A hole is subtracted from cylindrical surface as shown in Figure 4.16. This hole (cross hole) passes through axis of the cylinder. In Figure 4.16, cha_y indicates the position of the cross hole from origin. When a hole is made on surface then either of the ends are B-Splines. So, Edge curve is constructed by two lines and two B-Splines. Its radius is found from the `CYLINDRICAL_SURFACE` of corresponding `ADVANCED_FACE` string in STEP file. Position of cross hole is recognized if axis y coordinate of cross hole (cha_y) lies between external cylinder circle centers y coordinate ($cy1-cy2$) then cross hole is on that external cylinder.

Axis of cylinder and cross hole is found using `axis2_placement_3D` string in STEP file. Axis coordinates for cylinder is (cya_x, cya_y, cha_z) and cross hole is (cha_x, cha_y, cha_z) . If external cylinder axis z coordinate is equal to cross hole axis z coordinate then cross hole is passing through axis of external cylinder ($cha_z = cya_z$).

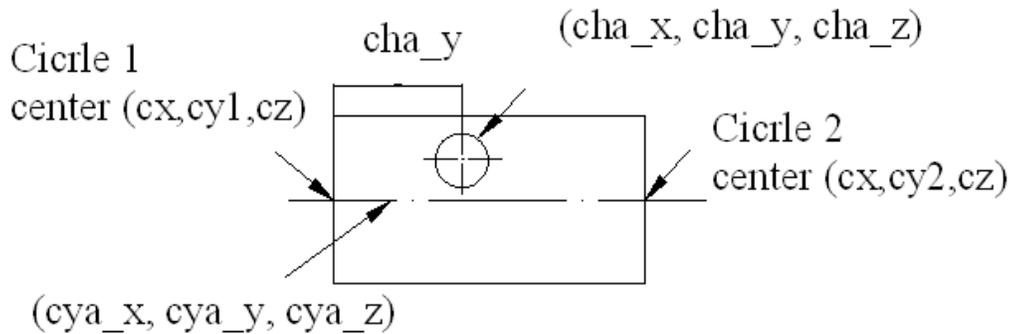


Fig. 4.16: Cross hole passing through axis line geometry

4.3.3 Recognition of a Cylindrical Cross Hole Offset from Axis Line

Figure 6.3 shows a cross hole of offset from external cylinder. As already explained axis of cross hole is found from AXIS_PLACEMENT string in STEP file. From this axis coordinates for both cylinder and cross hole is determined. If cross hole axis z coordinate is greater than the axis z coordinate of external cylinder ($a_z > cya_z$) then cross hole is above the axis of external cylinder. If cross hole axis z coordinate is less than the axis z coordinate of external cylinder ($a_z < cya_z$) then cross hole is below the axis of external cylinder. Difference of these two values gives the offset value.

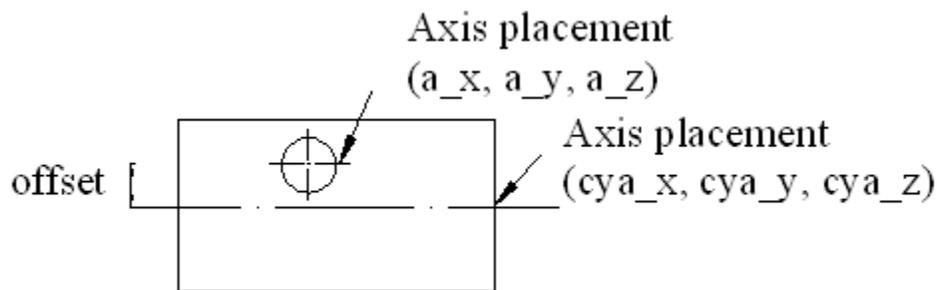


Fig. 4.17: Cross hole offset from axis line geometry

4.3.4 Recognition of a cylindrical cross hole inclined to axis line

Cross hole can be inclined to axis of a cylinder. This can be recognized from extracted data of a STEP file. As already explained edge curve is constructed by two lines for a cross hole. These two lines are parallel to axis of a cross hole. Inclination of line indicates inclination of cross hole axis. Line is constructed by two Cartesian points P1 and P2 with coordinates (x_1, y_1, z) and (x_2, y_2, z) respectively as shown in Figure 4.18. Inclination angle (α) is found using the following formula:

$$\tan \alpha = (y_2 - y_1) / (x_2 - x_1)$$

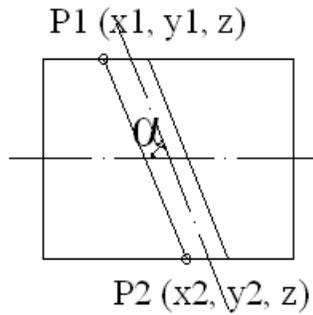


Fig. 4.18: Cross hole inclined to axis line geometry

4.3.5 Recognition of a Cylindrical Cross Hole - Through or Blind Feature

A cross hole may be a through hole or a blind hole. When cross hole subtracts on either ends of the surface of a cylinder then it is through hole. This can be recognized from STEP file with two bsplines in edge curve construction. When cross hole is subtracted from one end of a surface then other end is circle. From this it can be concluded that cross hole is blind. Cross hole depth can be found with the difference of circle center x coordinate of cross hole and external cylinder circle radius(R) as shown in Figure 4.19.

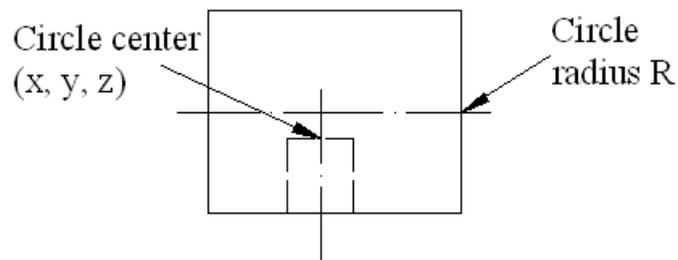


Fig. 4.19: Cross hole through or blind feature geometry

In this chapter, an attempt is made to apply rule based approach in the recognition of features like cylinder, cone, torus, sphere, cross holes etc. In the ensuing chapter various special features are considered and are presented.